

**MCGINN & GIBB, PLLC**  
**A PROFESSIONAL LIMITED LIABILITY COMPANY**  
**PATENTS, TRADEMARKS, COPYRIGHTS, AND INTELLECTUAL PROPERTY LAW**  
**8321 OLD COURTHOUSE ROAD, SUITE 200**  
**VIENNA, VIRGINIA 22182-3817**  
**TELEPHONE (703) 761-4100**  
**FACSIMILE (703) 761-2375; (703) 761-2376**

**APPLICATION  
FOR  
UNITED STATES  
LETTERS PATENT**

**APPLICANT'S:     YASUHIRO NAKAMURA, ET AL.**

**FOR:                 MOTOR-DRIVEN TYPE POWER STEERING  
                             APPARATUS**

**DOCKET NO.:       K06-165049M/TBS**

## MOTOR-DRIVEN TYPE POWER STEERING APPARATUS

### BACKGROUND OF THE INVENTION

The invention relates to a motor-driven type power  
5 steering apparatus using a motor as a source of generation of  
steering-assisting power.

A motor-driven type power steering apparatus for a  
vehicle includes a motor for steering-assisting purposes, and  
10 a reduction gear mechanism for transmitting a rotational force  
of the motor to a steering unit. The power steering apparatus  
assists the operation of the steering unit corresponding to the  
rotation of the steering unit by the rotation of the motor so  
that the driver's labor, required for the steering operation,  
15 can be reduced.

The reduction gear mechanism includes a worm serving as  
a drive gear which rotates in accordance with the rotation of  
the motor, and a worm wheel serving as a driven gear which meshes  
20 with the worm.

In the motor-driven type power steering apparatus using  
such a reduction gear mechanism, in order to reduce the amount  
of backlash in meshed portions of the worm and worm wheel so  
as to reduce rattle noise due to the backlash during the steering  
25 operation, the worm, the worm wheel, bearings, a housing, etc.,

are suitably selected and assembled (so-called stratified assembly) so that the rotation-axis distance between the axis of rotation of the worm and the axis of rotation of the worm wheel can fall within an allowable range. However, much time  
5 is required for this assembling operation.

There is known the type of motor-driven type power steering apparatus (for example, JP-A-2002-96749) in which a shaft portion of a worm disposed close to a motor and a shaft  
10 portion of the worm disposed remote from the motor are rotatably supported on a housing through respective rolling bearings, and a rubber ring is mounted on an outer peripheral surface of the motor-remote-side shaft portion of the worm, and the worm is urged or pressed toward the worm wheel by an elastic restoring  
15 force of the rubber ring so as to reduce the rotation-axis distance, thereby reducing the amount of backlash in meshed portions of the worm and worm wheel.

However, in the related motor-driven type power steering  
20 apparatus of the above construction in which the amount of backlash is reduced by the use of the rubber ring, each time the steering operation is effected, a load and a rotational torque are applied to the rubber ring in a radial direction, and therefore the rubber ring is liable to be subjected to  
25 deterioration such as permanent set in fatigue. And besides,

the degree of freedom for setting a preload by the urging force is relative low since the elastic restoring force of the rubber ring itself urges the worm.

5

#### SUMMARY OF THE INVENTION

This invention has been made in view of the above circumstances, and a main object of the invention is to provide a motor-driven type power steering apparatus in which a drive gear can be moved in directions to increase and decrease the rotation-axis distance, and besides a structure around the drive gear can be made compact.

In order to solve the aforesaid object, the invention is characterized by having the following arrangement.

- (1) A motor-driven type power steering apparatus comprising:
- 15 a drive gear connected to an output shaft of a motor;
  - a driven gear in mesh with the drive gear, which is connected to a steering unit;
  - a bearing for supporting one end of the drive gear;
  - a support portion in which the bearing is disposed; and
  - 20 a curved leaf spring which has a length larger than a peripheral length of the bearing and fitted between the bearing and the support portion in a resiliently deformed state, wherein the curved leaf spring urges the bearing so that a distance between an axis of the driven gear and an axis of the drive gear
  - 25 decreases.

(2) The apparatus according to (1), wherein the support portion includes a recess into which opposite ends of the curved leaf spring are inserted, and which is located distant from the axis of the driven gear with respect to the axis of the drive gear.

(3) The apparatus according to (2), wherein the curved leaf spring includes an abutment portion formed adjacent to the end thereof and a bent portion projected outwardly from the abutment portion, the abutment portion abutting against an outer peripheral surface of the bearing and the bent portion being inserted into the recess of the support portion.

(4) The apparatus according to (1), wherein the support portion has a hole in which the bearing is disposed and which has a substantially oval shape such that a radius between a center of the drive gear and a first side region of the hole which is located distant from the axis of the driven gear with respect to the center is larger than a radius between the center and a second side region which is located close to the axis of the driven gear with respect to the center.

(5) The apparatus according to (1), wherein the end of the drive gear supported by the bearing is distant from the motor

with respect to the other end.

(6) The apparatus according to (1) further comprising a pressing member for pressing the drive gear in a direction away  
5 from the motor,

wherein the curved leaf spring includes a spring piece portion for pressing the bearing toward the motor.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 Fig. 1 is an enlarged cross-sectional view showing the construction of a reduction gear mechanism of a motor-driven type power steering apparatus of the invention.

Fig. 2 is a cross-sectional view showing the overall construction of the motor-driven type power steering apparatus  
15 of the invention.

Fig. 3 is a perspective view showing the construction of a shaft coupling used in the motor-driven type power steering apparatus of the invention.

Fig. 4 is a cross-sectional view taken along the line IV-IV  
20 of Fig. 1.

Fig. 5 is a perspective view showing the construction of a curved leaf spring used in the motor-driven type power steering apparatus of the invention.

Fig. 6 is a cross-sectional view showing a major portion  
25 of a second embodiment of a motor-driven type power steering

apparatus of the invention.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A preferred embodiment of the present invention will now  
5 be described in detail with reference to the drawings.

##### Embodiment 1

Fig. 1 is an enlarged cross-sectional view showing the  
construction of a reduction gear mechanism of a motor-driven  
type power steering apparatus of the invention, and Fig. 2 is  
10 a cross-sectional view showing the overall construction of the  
motor-driven type power steering apparatus.

The motor-driven type power steering apparatus comprises  
a motor 1 for steering-assisting purposes, the reduction gear  
15 mechanism A, and a steering unit 5 connected to the reduction  
gear mechanism A. The reduction gear mechanism A includes a worm  
3 serving as a drive gear, which is coupled to an output shaft  
1a of the motor 1 through a shaft coupling 2, and a worm wheel  
4 serving as a driven gear which meshes with the worm 3.

20

The steering unit 5 includes: a first steering shaft 51  
which is connected at one end thereof to a steering wheel B for  
steering purposes and has a tubular portion 51a at the other  
end thereof; a torsion bar 52 which is received in the tubular  
25 portion 51a of the first steering shaft 51, is connected at one

end thereof to the tubular portion 51a, and can be twisted by a steering torque applied to the steering wheel B; and a second steering shaft 53 which is connected at one end thereof to the other end of the torsion bar 52, and is connected to the reduction gear mechanism A. The second steering shaft 53 is connected to a steering mechanism (not shown), for example, of the rack-and-pinion type via a universal joint.

The worm 3 of the reduction gear mechanism A has shaft portions 3a and 3b formed respectively at opposite ends thereof. The shaft portion 3a at one end of the worm is rotatably supported by a support member 7 of aluminum through a first rolling bearing 6, and is coupled to the output shaft 1a of the motor 1. The shaft portion 3b at the other end is supported by the support member 7 through a second rolling bearing 8. The shaft portions 3a and 3b are press-fitted in inner rings of the rolling bearings 6 and 8, respectively.

The worm wheel 4 comprises an annular toothed member 41, and a core member 42 of metal fixed to the inner side of the annular toothed member 41. The core member 42 is fixedly mounted or fitted on the second steering shaft 53 intermediate the opposite ends thereof.

The support member 7 includes a first receiving portion 7a receiving the worm 3 therein, and a second receiving portion

7b receiving the worm wheel 4 therein. The shaft portions 3a and 3b of the worm 3 are rotatably supported by the first receiving portion 7a through the rolling bearings 6 and 8, and the worm wheel 4 is supported by the second receiving portion 5 7b through the second steering shaft 53 and two rolling bearings 9 and 10 fitted on the second steering shaft 53.

The first receiving portion 7a is elongated in the direction of the axis of the worm 3. A support hole 71, an annular 10 groove 72 and a motor-mounting portion 73 are provided at one longitudinal end portion of the first receiving portion 7a. The rolling bearing 6 is loosely fitted in and supported by the support hole 71 communicating with the annular groove. A 15 retainer ring 11 in the form of a wavy plate is fitted in the annular groove 72, and comes in contact with an outer ring 6b of the rolling bearing 6 to limit the movement of this rolling bearing 6 in the axial direction. The motor 1 is mounted on the motor-mounting portion 73.

20 Fig. 3 is a perspective view showing the construction of the shaft coupling.

The output shaft 1a of the motor 1 and the shaft portion 3a of the worm 3 are coupled together through a shaft coupling 2. The shaft coupling 2 comprises first and second coupling 25 members 21 and 22 each having three meshing teeth 21a, 22a formed

at one end thereof, and an elastic toothed member 23 which is interposed between the coupling members 21 and 22, and has six meshing portions 23a to 23f formed on an outer peripheral surface thereof. The meshing portions 23a to 23f mesh with the meshing teeth 21a and 22a. Teeth surfaces of each teeth 21a, 22a of each coupling member 21, 22 are slanting such that the teeth 21a, 22a are decreasing in size gradually from its proximal end toward its distal end and that the thickness of the teeth 21a, 22a is increasing gradually from a rotation axis-side edge toward an outer periphery-side edge.

As to the elastic toothed member 23, the meshing portions 23a to 23c for respectively meshing with the meshing teeth 21a, and the meshing portions 23d to 23f for respectively meshing with the meshing teeth 22a are alternately arranged in the circumferential direction. The meshing teeth 21a mesh respectively with the meshing portions 23a to 23c, while the meshing teeth 22a mesh respectively with the meshing portions 23d to 23f, and by doing so, a gap between each of the coupling members 21 and 22 and the elastic toothed member 23 in the rotational direction, as well as a gap between the two in the axial direction, is eliminated, and besides the worm 3 is urged in the direction away from the motor. The first coupling member 21 is fitted on the output shaft 1a, and the second coupling member 22 is serration-fitted on the shaft portion 3a. The

meshing portions 23a to 23c and the meshing portions 23d to 23f extend in opposed directions in the axial direction, and the meshing engagement is effected in such a manner that an axial force is exerted between the meshing portions 23a to 23c and the meshing teeth 21a and also between the meshing portions 23d to 23f and the meshing teeth 22a. With this construction, the second coupling member 22 is urged away from the motor with respect to the first coupling member 21 which is prevented by the output shaft 1a from moving in the axial direction.

10

A support hole 74 is provided at the other end portion of the first receiving portion 7a, and the second rolling bearing 8 and a curved leaf spring 12, fitted on the rolling bearing 8, are supported in this support hole 74. The support hole 74 has a generally oval shape such that a radius between a center of the worm 3 and a first side region 74a of the support hole which is located distant from the axis of rotation of the worm wheel 4 with respect to the center in a radius direction of the support hole 74 is larger than a radius between the center and a second side region 74b which is located close to the axis of rotation of the worm wheel 4 with respect to the center in the radius direction. The curved leaf spring 12 can be resiliently deformed between a peripheral surface of the first side region 74a and the rolling bearing 8, and besides there is provided a gap for allowing the rolling bearing 8 to be moved

25

in directions to increase and decrease a rotation-axis distance H between the axis, of rotation of the worm 3 and the axis of rotation of the worm wheel 4. A recess 74c for receiving end portions 12a and 12b of the curved leaf spring 12 is formed in the peripheral surface of the first side region 74a, and is disposed substantially centrally of the peripheral length of this first side region 74a.

Fig. 4 is an enlarged cross-sectional view taken along the line IV-IV of Fig. 1, and Fig. 5 is a perspective view showing the construction of the curved leaf spring.

The curved leaf spring 12 is constituted by a strip or band of spring steel, an intermediate portion of which is curved into a substantially round shape along the outer peripheral surface of the rolling bearing 8, and has a length larger than the peripheral length of the rolling bearing 8. A notch 12c is formed in one end portion 12a of this curved leaf spring, and is disposed centrally of the width thereof, while notches 12d and 12d are formed respectively in opposite side edge portions of the other end portion 12b. The end portion 12a is fitted in the notches 12d and 12d while the end portion 12b is fitted in the notch 12c, and by doing so, the end portions 12a and 12b can be arranged to intersect each other without increasing the width, and besides the end portions 12a and 12b are spaced from the outer peripheral surface of the rolling

bearing 8, that is, spaced from a circle in which a curved portion 12e lies. The end portions 12a and 12b of the curved leaf spring 12 are received in the recess 74c, and are resiliently deformed in this recess 74c to urge the worm 3 through the rolling bearing 8 in the direction to decrease the rotation-axis distance H.

A plurality of spring piece portions 12f are formed integrally on one side edge of the curved portion 12e of the curved leaf spring 12, and are spaced from one another in the circumferential direction. The spring piece portions 12f are held against a side surface 74d of the support hole 74 to urge the second rolling bearing 8 toward the motor 1. The spring piece portions 12f project from the curved portion 12e, and are inclined inwardly relative to the peripheral surface of the curved portion 12e, and these spring piece portions 12f, when held against the side surface 74d of the support hole 74, are resiliently deformed, and a reaction force of their resilient restoring force is applied to the worm 3 via an outer ring 8b, balls, an inner ring 8a of the second rolling bearing 8, thereby urging the worm 3 toward the motor 1.

The curved leaf spring 12, made of spring steel, is contacted at its inner surface with the outer ring 8b of the rolling bearing 8 made of steel, and is contacted at its outer surface with the support member 7 made of aluminum. Therefore,

a cushioning material is coated on each of the inner and outer surfaces of the curved leaf spring 12 over an entire area thereof so as to prevent noises from being produced by the above contact. Noises are more liable to be produced when the curved leaf spring is held in contact with the rolling bearing 8 as compared with the case where the curved leaf spring is held in contact with the support member 7, and therefore without coating the cushioning material on both of the inner and outer surfaces of the curved leaf spring 12, the cushioning material may be coated only on the inner surface of the curved leaf spring 12.

A torque sensor 13 is contained in the support member 7, which detects a steering torque applied to the steering wheel B on the basis of the amount of a relative rotational displacement between the steering shafts 51 and 53 which corresponds to the amount of twisting of the torsion bar 52. The driving of the motor 1 is controlled in accordance with a torque amount or the like detected by the torque sensor 13.

In the motor-driven type power steering apparatus of the above construction, to incorporate the worm 3 into the apparatus, the curved leaf spring 12 is inserted into the support hole 74 in the support member 7, and the end portions 12a and 12b of the curved leaf spring 12 are inserted into the recess 74c, thereby positioning the curved leaf spring 12, that is, setting

the direction of urging of the rolling bearing 8 by the end portions 12a and 12b. Then, the worm 3, having the rolling bearings 6 and 8 press-fitted respectively on the shaft portions 3a and 3b, is inserted into the first receiving portion 7a, and  
5 the second rolling bearing 8 is inserted into the curved leaf spring 12, and the first rolling bearing 6 is loosely fitted into the support hole 71, and the retainer ring 11 is fitted in the annular groove 72, thereby limiting the movement of the worm 3 in the axial direction.

10

The end portions 12a and 12b of the curved leaf spring 12, urging the incorporated worm 3, are received in the recess 74c in the support member 7, and the rolling bearing 8 and the worm 3, supported by the rolling bearing 8, are urged by the  
15 resilient force of the end portions 12a and 12b in the direction (that is, in the direction toward the worm wheel) to decrease the rotation-axis distance H. Therefore, the amount of backlash in the meshed portions of the worm 3 and worm wheel 4 can be reduced, and even when the amount of wear of the teeth  
20 of the worm 3 and worm wheel 4 increases or even when the worm 3 and worm wheel 4 contract due to the low temperature, the amount of backlash in the meshed portions can be reduced whereby suppressing the rattle noise.

25

And besides, the end portions 12a and 12b of the curved

leaf spring 12 can be resiliently deformed in the directions to increase and decrease the rotation-axis distance  $H$ , and therefore even when the worm wheel 4, having the annular toothed member 41 made of a synthetic resin, is expanded by a rise in  
5 the atmosphere temperature, or is expanded upon absorbing of moisture, a meshing resistance produced at the meshed portions is prevented from increasing, so that the worm 3 and the worm wheel 4 can be smoothly rotated.

10 The curved leaf spring 12 is formed by curving the sheet of metal (such as spring steel) having the length larger than the peripheral length of the rolling bearing 8, and therefore as compared with the rubber ring used in the conventional apparatus, the curved leaf spring 12 has higher durability, and  
15 besides the degree of freedom for setting the preload can be made relatively high. In addition, as compared with the conventional apparatus using the rubber ring, the structure around the worm gear 3 can be made compact, and therefore the overall size of the motor-driven type power steering apparatus  
20 can be reduced.

Furthermore, with virtue of the provision of the notches 12c and 12d, the end portions 12a and 12b of the curved leaf spring 12 intersect each other, and therefore the curved leaf spring 12 can be inserted in the support hole 74 without  
25 increasing its width relative to the rolling bearing 8, and the

resilient restoring force of the end portions 12a and 12b is easily applied to the rolling bearing 8.

The curved leaf spring 12 is curved along the outer  
5 peripheral surface of the rolling bearing 8, and a gap between  
the curved leaf spring 12 and the rolling bearing 8, as well  
as a gap between the curved leaf spring 12 and the second side  
region 74b of the support portion 74 are eliminated, and  
therefore the movement of the worm 3 in a direction intersecting  
10 the directions of the rotation-axis distance H is limited. A  
tooth trace of each of the worm 3 and the worm wheel 4 is made  
spiral in the rotational direction relative to the axis of  
rotation. When a rotational torque is applied from the worm 3  
to the worm wheel 4, that is, when the steering operation is  
15 assisted by the rotation of the motor 1, a component of force  
(hereinafter referred to as "meshing reaction force") is  
produced so as to move the worm 3 in the radial direction along  
the tooth trace of the worm wheel 4. The worm 3 is pressed by  
this meshing reaction force, and the second rolling bearing 8  
20 is pressed by this pressing force in the direction intersecting  
the directions of the rotation-axis distance H. However, the  
movement of the rolling bearing 8 by this pressing force and  
hence the movement of the worm 3 can be limited with the  
above-described construction.

25

The worm 3 thus urged by the curved leaf spring 12 is oscillated with respect to the support portion for the first rolling bearing 6 in the directions of the rotation-axis distance H. Since the first rolling bearing 6 is loosely fitted in the support hole 71, the second rolling bearing 8 together with the worm 3 can be pivotally moved. And besides, the worm 3 is coupled to the output shaft 1a via the shaft coupling 2 having the elastic toothed member 23, and therefore the amount of pivotal movement of the worm 3 is increased. Therefore, even when the amount of expansion of the worm wheel 4 having the annular toothed member 41 made of a synthetic resin due to a temperature rise and the absorption of moisture increases, the meshing resistance produced at the meshed portions is prevented from increasing, so that the worm 3 and the worm wheel 4 can be smoothly rotated.

The worm 3 is urged away from the motor 1 by the shaft coupling 2 comprising the first and second coupling members 21 and 22 and the elastic toothed member 23 interposed between the coupling members 21 and 22, and is urged toward the motor 1 by the spring piece portions 12f of the curved leaf spring 12. Therefore, the forces acting on the worm 3 in the axial direction can be balanced, so that the rotating performance of the worm 3 can be enhanced.

The worm 3 is connected to the output shaft 1a via the shaft coupling 2 having the elastic toothed member 23, and therefore the elastic toothed member 23 prevents the propagation of noise produced at the motor 1, and besides prevents any noise from being produced at the shaft coupling portion. The movement of the rolling bearing 6 is prevented by the retainer ring 11 comprising the wavy plate, and therefore the efficiency of the operation for mounting the rolling bearing is enhanced as compared with the case where the rolling bearing is fixed by the use of a threaded ring.

#### Second Embodiment

Fig. 6 is a cross-sectional view showing a major portion of a second embodiment of a motor-driven type power steering apparatus of the invention.

In the motor-driven type power steering apparatus of the second embodiment, a curved leaf spring 12, generally similar to the curved leaf spring 12 of the first embodiment, has abutment portions 12g and 12g for abutting against an outer peripheral surface of a second rolling bearing 8, which is formed adjacent respectively to end portions 12a and 12b thereof, and bent portions 12h and 12h project outwardly from the abutment portions 12g and 12g, respectively. Each of the end portions 12a and 12b can be resiliently deformed to be turned about the corresponding abutment portion 12g.

In the second embodiment, the bent portions 12h and 12h are located such that a peripheral length between the two bent portions 12h and 12h is smaller than the peripheral length of the second rolling bearing 8. When the end portions 12a and 12b are inserted into a recess 74c in a support hole portion 74, and are resiliently deformed, the abutment portions 12g and 12g abut against the outer peripheral surface of the second rolling bearing 8.

10

In the second embodiment, the abutting portions 12g and 12g, disposed adjacent respectively to the end portions 12a and 12b, abut against the outer peripheral surface of the second rolling bearing 8, and the end portions 12a and 12b can be resiliently deformed to be turned about these abutment portions 12g and 12g, respectively, and therefore the degree of freedom for setting a preload can be made higher.

15

The other constructions and operations are similar to those of the first embodiment, and therefore corresponding parts are designated by identical reference numerals, respectively, and detailed description thereof, as well as description of effects of the operations, will be omitted.

20

In the above embodiments, although the shaft portion 3b of the worm 3 is supported by the rolling bearing 8, this shaft

25

portion may be supported by any other suitable bearing such as a slide bearing. Although the worm 3 is urged away from the motor by the shaft coupling 2, the means for urging the worm 3 away from the motor may comprise a resilient member such as  
5 a coil spring.

In the above embodiments, although there is used the worm gear having the worm 3 serving as the drive gear and the worm wheel 4 serving as the driven gear, a bevel gear or a hypoid gear may be used.

10

As described above in detail, according to the invention, the curved leaf spring has higher durability as compared with the related apparatus using the rubber ring, and besides the degree of freedom for setting the preload can be made relatively  
15 high. Furthermore, as compared with the conventional apparatus using the rubber ring, the structure around the drive gear can be made compact, and therefore the overall size of the motor-driven type power steering apparatus can be reduced.

20 Further according to the invention, the degree of freedom for setting the preload can be made higher.

According to the invention, the axial forces, acting on the drive gear, can be balanced, so that the rotating  
25 performance of the drive gear can be enhanced.